Sound Science: Revised annotated outline

April 24, 2006

Executive Summary (10 -15 pages): Brief summary of why an ecosystem-scale approach is needed in Puget Sound, the concept of using ecosystem goods and services to evaluate linkages and tradeoffs; Key Findings; Implications for Management. This section will ultimately include a brief description of each of the issue papers.

1. **Problems and Opportunities for Puget Sound** (target for final report 2-3 pages)
   This introductory section will define the problem and identify the opportunities that we are faced with in the next decades. A variety of recent "blue-ribbon" commissions have pointed to ecosystem-based management as the most appropriate approach for management of marine resources. This is consistent with recent, more local direction.

   1.1 Summarize key indicators of Puget Sound and their status (references: State of the Sound, Puget Sound salmon recovery plan).

   1.2 Describe the Governor's recent charge to the Puget Sound Partnership, noting that it describes a vision for thriving human and natural systems in Puget Sound. Such a dual goal contains multiple objectives with the potential for tradeoffs between those objectives.

   1.3 Express the Governor's charge as a set of general management questions for Puget Sound:
   - What are the natural drivers of ecosystem change?
   - How has the Puget Sound ecological condition changed?
   - How have ecosystem services provided to the Puget Sound region changed?
   - What are the current drivers of ecosystem change?
   - What are important uncertainties of ecosystem change that affect our ability to take action and predict ecosystem responses?
   - How might Puget Sound ecosystems change under various plausible scenarios of future conditions and actions?
   - What options exist to manage ecosystems sustainably?

2. **Management of Puget Sound on an Ecosystem Scale** (5-10 pages)
   Provide an overview of the concept of ecosystem-based management, goods and services from the Puget Sound ecosystem and human uses of and interactions with the ecosystem.

   2.1 Define the conceptual framework. Changes in ecosystems due to natural and human causes result in changes in the goods and services provided by the ecosystem, thus affecting the well-being of humans and other species (Fig. 2-1).

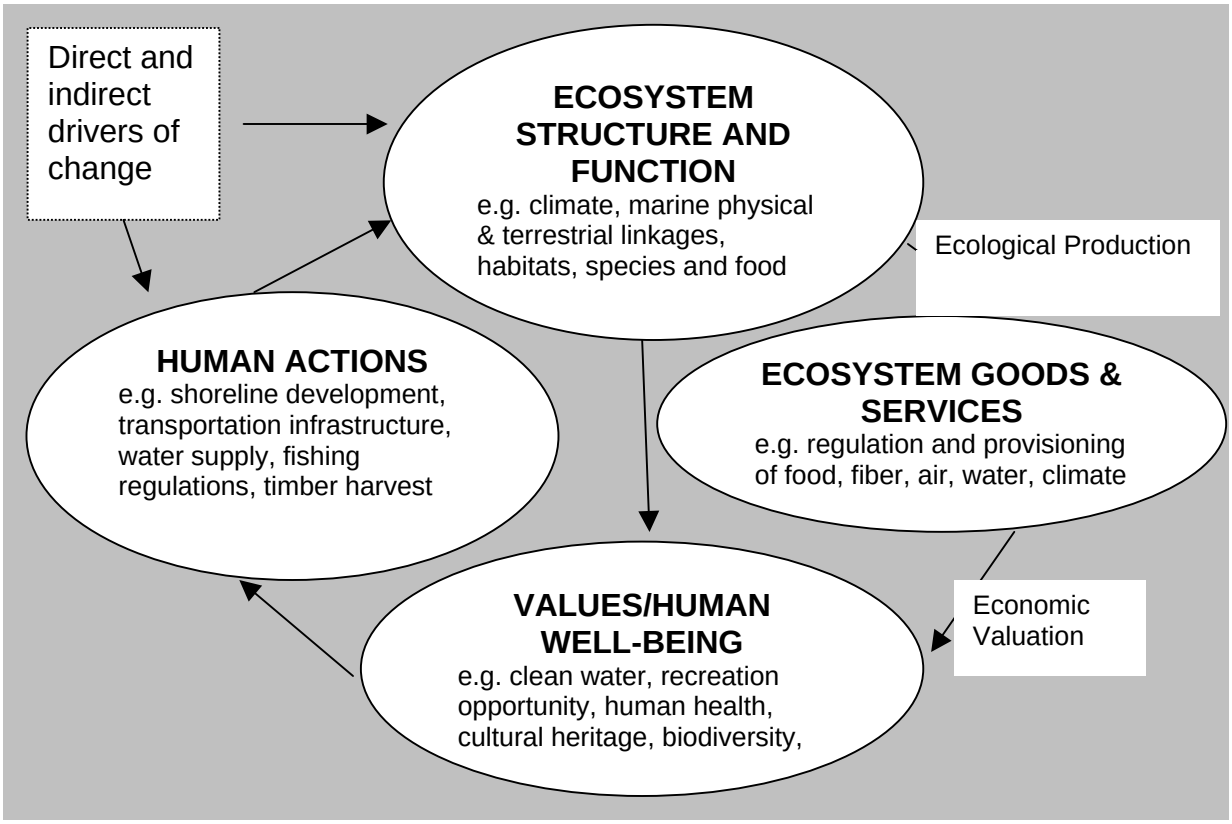

Figure 2-1: Relationship of Ecosystem Structure and Function and Human Well-Being (adapted from National Research Council 2004 and Millennium Ecosystem Assessment 2005).

2.2 Describe the primary drivers of ecosystem change.

2.3 Articulate explicitly the services and goods humans get from the Puget Sound ecosystem.

- Box – list of services and goods from Puget Sound (e.g., food/forage, property values, waste disposal, recreation, transportation/shipping, etc.)

2.4 Ecosystem values and how they support human well-being, interconnectedness of human actions and ecosystem functioning.

- Example of oceans and human health box

2.5 Human uses of and interactions with the ecosystem affect the value of other uses and interactions, thus a more systems-oriented approach to ecosystem management is appropriate. Alternative future conditions can be analyzed as scenarios. Tradeoffs in the values that humans can derive from the ecosystem under different management scenarios can be explicitly considered.

3. The Puget Sound Ecosystem: Past and Present (20 pages)

Brief description of the Puget Sound ecosystem, its food webs, habitats and processes, and how it has changed over time. Emphasize defining and unique features of Puget Sound and connectivity between actions, processes and ecosystem goods and services.

3.1 Overview of Puget Sound

- Geographic definition as used here (includes Strait of Juan de Fuca)
- Physical parameters (how big, how deep etc.) and unique situation as an urbanizing fjord with steep bathymetry, narrow fringing nearshore, and sills that restrict flushing of marine basins.
- Defining features include major mountain ranges, variation in elevation and precipitation in a small region, glacier-fed and rainfall dominated river systems.
- Introduce subtopics – physical processes that affect habitats and species distribution and abundance. Note that as a result of connections between these aspects, none of them are static – processes, habitats and species change in both short and the long time frames.

3.2 Inputs/connections between terrestrial, freshwater and marine habitats. (Brief summary including processes/linkages; nutrient cycling; and movement of wood and sediment via freshwater inputs to estuarine, nearshore and marine habitats.)

- Figure: Fraser River and other Puget Sound rivers as the main sources of freshwater to the Sound.
- Box on Elwha

3.3 Water circulation in Puget Sound

- Description to be based on a new circulation figure in process
- Widespread features
  - Coastal upwelling and connections from the open ocean to Puget Sound
  - Note that conditions are different in Strait of Juan de Fuca and Central Puget Sound/Hood Canal
  - Unique physical attributes-- e.g., sills mean that flushing is not as fast or complete as in other estuaries/bays.
  - Contribution of fresh water inflow from rivers to circulation patterns
- Local phenomena
  - Mixing zones
  - Recirculation (such as around Vashon)

3.4 Climate and ocean processes

- (Overview figure placing local climate in global context)
- Local climate drivers and spatial variation -- drainage basin for 2 major mountain ranges with snow pack; glacially driven runoff in some streams, rainshadow from Olympic mountains, convergence zone.

- General pattern of connections between global and local climate, terrestrial, freshwater, and ocean conditions
  - Prevailing winds contribute to upwelling, etc. (and air quality impacts from global sources such as Asia).
  - Japanese current with moderating temperature and precipitation conditions
  - Temporally variable climate and ocean processes – el Nino and PDO

3.5 Habitat types and distribution

- Overview
  - Unique features include the relatively narrow band of nearshore habitats; geology—lots of sands and glacial outwash as substrate on land and in water.
  - purpose not to reclassify habitats (Box with list of efforts to date at habitat classification)
  - Some key determinants are depth and its correlates (light and temperature), exposure, salinity and substrate.
  - Habitats can occur at all kinds of scales (an oyster shell is "habitat" as is all "deep water" in Puget Sound.)
  - Some habitats are created by organisms (mussel beds, eelgrass, kelp beds).
- Habitat maintenance and formation dependent upon physical processes (above), such as sediment input, circulation, etc. Those that are created and maintained by organisms are dependent on interspecific interactions as well.
- Clinal differences (figure showing differences along each cline)
  - Depth
  - N to S (i.e. S. Sound to San Juans)
  - Fine to coarse (solid) substrate
  - Protected to exposed
  - Freshwater, to brackish to marine
- Some example habitats (each one a box)
  - Eelgrass beds
  - Rocky reefs
  - Tide flats
  - Open water/pelagic
  - Salt marsh

3.6 Species and their interactions

- Overview –
  - Unique features of Puget Sound species including diversity (# of species in different taxa represented); major bio-geographic break between the terrestrial flora/fauna on Olympic Peninsula and rest of Puget Sound; overlap in species ranges from northern and southern groups in marine waters
  - short description of trophic groups
  - species interactions (predation, competition, parasitism, etc.)

- Seasonal use vs. resident species
- Simple description of Puget Sound food webs (Figure in development)
  - Include detrital pathways, terrestrial inputs and primary producers as basis
  - Strive to show connections between habitats made by motile organisms
  - 2-3 examples of food web interactions (detailed description of connections)
  - Parasites
  - Pathogens and biotoxins
  - 1-2 examples (Box on HAB effects on marine mammals (?))

3.7 Humans and ecosystem change:

- Timeline of some major human activities affecting PS ecosystem in the last 2 centuries; consequences to the ecosystem.
  - Human settlement patterns, uses, and impacts on Puget Sound (map)
  - Land uses – timber, ag, aquaculture, transportation, urbanization (maps)
  - Marine extractive activities – fishing/other foraging, aquaculture
- Describe increasing influence of humans as drivers of ecosystem change to 3.2 – 3.6 above (both positive and negative).
- Patterns of land use
- Change in species abundance. Very brief summary of pollutants and contaminants
  - Include a box summarizing a few actual changes in ecosystem goods and services (the results of 2 centuries of change) e.g. increase # of polluted shellfish beds, decline in total salmon harvest, loss of saltmarsh habitat acreage; increases in other ecosystem services such as water supply to municipalities and/or distribution
  - Change in habitat abundance and/or distribution
  - Changes to physical processes
  - Restoration and preservation activities
  - Patterns of extraction (terrestrial, freshwater and marine)

4. The Future of Puget Sound (30+ pages – approx 5 pages for each topic)
The introduction to this section would indicate that the issues below have surfaced as the primary drivers of change to the Puget Sound ecosystem and the services it provides.

Where possible, each issue should include the following:

- *Relationship to the conceptual figure on ecosystem wide approach (Fig 2-1) and which pieces are being illustrated.*
- *Boxes that describe linkages among issues.*
- *Answers to the following questions:*
  What conditions have changed; what are the trends?
  What changes and consequences are anticipated in the next 2 to 4 decades?
  How do these changes relate to our use of and interaction with the Puget Sound ecosystem as a whole?
  What are the major gaps and uncertainties in our scientific knowledge?

4.1 Climate Change and the Puget Sound Ecosystem: Likely changes to climate in the Puget Sound region and consequences for the ecosystem.

- Brief overview of the CIG report on PS climate impacts and implications.
- Possible topics to cover:
- How changes in physical characteristics – water temperature, precipitation (freshwater inputs), water quality – might change species and habitat distributions and therefore change goods and services (e.g. primary physical changes; increases in peak flows, reduced low flows, sea level rise, changes in services and potential tradeoffs).
  - Changes in environmental conditions and thus food web changes – non-indigenous species, pathogens, etc.
  - Potential effects on water supply
- What do we know about ocean condition changes due to climate change and the effects of ocean conditions on PS? E.g. changes in salinity, temperature, and thus nutrients, etc.
- What are the potential effects of future climate on protection and restoration efforts in Puget Sound? (Box--Snohomish climate/ land use and restoration strategies?)
- Describe briefly how land use planning or other actions interact with potential changes resulting from climate
- Key informational gaps and uncertainties.

4.2 Forming and Maintaining Habitats: Description of trends in habitat quality and quantity in Puget Sound, causes and consequences of that change.

- Trends in habitat distribution, area and quality in Puget Sound.
- What has caused these changes in habitat? What are the changes to relevant processes that form and maintain habitat?

- How do human modifications of, and interaction with, habitats affect ecosystem goods and services?
  - Include 2-3 substantial and important examples (e.g. shoreline modification to eelgrass to herring to salmon to orca to whale watching).
  - Include water quality impacts from stormwater, other freshwater and atmospheric sources.
  - Include a box describing Hood Canal DO as example of changes in pelagic habitat condition, and how the work there is to decipher the primary causes of that change.
- Key informational gaps and uncertainties.

4.3 Species and their Interactions: Top Down and Bottom Up Changes

- Trends in species abundance, both native and introduced
- Human interaction with food webs and consequences.
  - Reductions in top-level predators (non-human) and resulting changes in other species and ecosystem services (refer to eco-tourism industries such as whale watching, kayaking, birding; also fishing)
  - Changes to species abundance and composition resulting from aquaculture, harvest. Tradeoffs in benefits to humans and costs to local species, benthic and pelagic habitats and the ecosystem services they provide.
  - Changes to ecosystem processes, such as nutrients and temperature and bottom-up impacts to species
- A case-study or example
- Key informational gaps and uncertainties
- Relationship to recovery strategies and ecosystem services.
  - Protection and/or recovery efforts that are focused on top-level predators that consider prey, competitors, predator and habitat needs are likely to be more successful.
  - Recovery strategies that consider human uses and interactions with the ecosystem, e.g. land use, harvest, input of contaminants will be more successful.
  - Relative effectiveness of multi-species management strategies that incorporate interaction with habitats, predators, prey and pathogens in achieving sustainable harvest.

4.4 Interactions between Natural and Human Systems in Puget Sound

Information about the relationship between natural, human systems is key to estimating ecosystem responses to alternative management approaches. Potential changes in human population growth and distribution across the landscape, and how these changes might interact with the rest of the ecosystem.

- Relationship to recovery strategies and ecosystem services.
- Patterns of human population growth (past and potential future)
- Effects of human behaviors as drivers of land use and marine water uses

- Effects of different land uses on ecosystem attributes (or ecosystem goods).
- Box – interactions between humans and ecosystem elements. (Use an example such as transportation needs and potential for marine zoning as a tool. Effects of different land uses on ecosystem attributes (or ecosystem goods).
- Alternative incentives and management approaches based on social science input.
- Connectivity and feedbacks between human and natural systems, alternative future scenarios, and implications for management.
- Key informational gaps and uncertainties.

4.5 Human Health and Well-being: The ways in which the Puget Sound ecosystem affects human wellness (physical, cultural, mental, etc.), and how changes to the ecosystem affect us directly (some of our goods and services). In each category describe how alternative futures could improve or worsen these situations.

- Human health: Trends, changes and potential consequences
  - Trends in contaminants (nutrients, pathogens and toxins) in the environment and in species. (Note that species can be useful sentinels for human health, such as migratory birds and bird flu.)
  - Effect on food sources and habitat for humans (swimming, living, etc.)
  - Toxins: Anthropogenic (PCBs, PBDEs, etc.), Biological (HABs)
  - Disease and pathogens
- Quality of life
  - Recreation and leisure
  - Tourism
  - Locations/species of cultural significance
- Thus human uses of and interactions with the ecosystem cause changes in ecosystem elements and thereby impact our health.
- Discuss alternative future scenarios—under different management implications associated with this issue.
- Key informational gaps and uncertainties related to human health, e.g., persistence of toxins, the need to quantify total contaminant loading in Puget Sound

4.6 Integrating the Sciences: Natural and Social Science Support for Decision-Making: Decision frameworks and how they can help organize existing information to support decisions now and help focus/prioritize monitoring and future research needs. Decision frameworks allow evaluation of tradeoffs, identification of key science gaps, and allow decision-making that will account for uncertain futures.

- Social Science: Connection between social science information and how it can be integrated into decision-making.
  - e.g. likely outcomes of alternative incentives on ecosystem goods or attributes; costs of alternative actions producing similar results

- drivers of human behavior and connection to feedback with natural drivers

- Natural Science: Connection between scientific information and how it can be integrated into decision-making processes.
  - e.g. likely outcomes on multiple ecosystem goods from a single ecosystem change or management strategy.
- Use of conceptual and quantitative decision support systems in decision-making on an ecosystem-wide level
  - Focusing on goals (human values) and using conceptual or quantitative models to help identify and weigh trade-offs and to choose between options.
  - Identify key information gaps that affect ability to make decisions.
- Ecosystem governance
  - How can science and policy interact more effectively to inform management in Puget Sound?
  - What is the existing structure of ecosystem management, how effective is it, and what are alternatives for the future?
  - [This section could end up as a series of questions directed to the partnership]

5. Key Findings

Should tie fairly directly to the issue papers in part 4.
Should include a few key science gaps.